



REMR TECHNICAL NOTE CS-MR-8.8

CASE HISTORY OF DAM REPAIR:
REMEDIAL WATERSTOPS

PURPOSE: To provide a summary of information on techniques used to repair waterstops in concrete hydraulic structures.

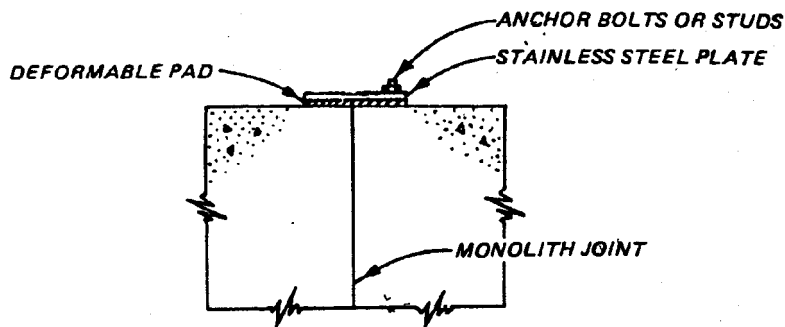
BACKGROUND: Nearly every concrete structure has joints that must be sealed to ensure the integrity and serviceability of the structure. This fact is particularly true of monolith joints in hydraulic structures such as concrete dams and navigation locks. Typically, these joints are sealed with embedded waterstops. Traditionally, waterstops have been subdivided into two classes: rigid and flexible. Most rigid waterstops are metallic: steel, copper, and occasionally lead. Flexible waterstops are made from a variety of materials; however, polyvinyl chloride (PVC) is probably the most widely used (Ref a).

Typical causes of waterstop failure include excessive movement of the joint which ruptures the waterstop, honeycombed concrete areas adjacent to the waterstop, contamination of the waterstop surface which prevents bond to the concrete, complete breaks in the waterstop because of poor or no splices. Since it is usually impossible to replace an embedded waterstop, grouting or installation of remedial waterstops is the repair measure most often used. Several types of remedial waterstops have been tried with various degrees of success and variation in cost.

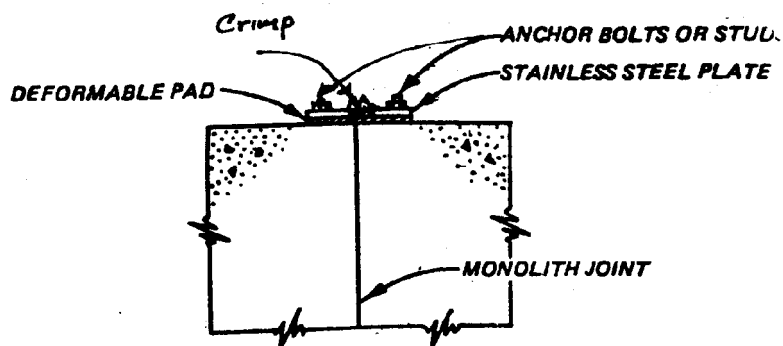
REPAIR TYPES: Generally, remedial waterstops are grouped into four basic types: surface plates, caulked joints, drill holes filled with elastic material, and chemically grouted joints. The type used depends on a number of factors, including joint width and degree of movement, hydraulic pressure in the joint, environment, type of structure, economics, available construction time, and access to the upstream joint face.

a. Surface plates:

- (1) Description. A plate-type surface waterstop (Figure 1) consists of a rigid plate, generally stainless steel, that spans the joint. It is backed with a neoprene or deformable rubber backing to assist in sealing the joint. The plate is attached to the monolith on one side of the joint with anchor bolts (Figure 1a). The anchors provide initial pressure on the deformable pad. Water pressure against the plate provides additional pressure so that the deeper the waterstop is in a reservoir, the tighter the plate presses to the surface of the joint. In situations where large movement between monoliths is expected, it might be useful to use a thin metal sheet with a crimp over the joint which will allow for the large movement (Figure 1b). This method allows the metal to be bolted to the monolith on both sides of the joint.



a. Plate attached to monolith
with anchor bolts



b. Crimp over joint

Figure 1. Typical plate type surface waterstop

- (2) Use. Surface plates have been used as remedial waterstops and as backup plates for caulked and grouted joint repairs. They are particularly useful when the repair site is freely accessible.
- (3) Advantages/Limitations. This type of waterstop has been used with varying degrees of success. It has the advantage of being a simple repair and, if applied to a joint that is exposed and not underwater, one that itself can be easily repaired. Repair materials are generally nontoxic and inexpensively obtained.

Access to the surface that is to receive the remedial waterstop is a necessity for this method. It does not function well where large movements between monoliths are expected. Potential problems with this type of repair include loosening of the anchor bolts, reverse hydrostatic pressure from water trapped behind the waterstop when the reservoir drops, mechanical abuse such as a barge tearing off the plate, ice pressure from moisture trapped behind the plate, and hardening of the flexible pad because of aging (Ref b).

b. Caulked Joints:

- (1) Description. This is a simple and economical repair method which is achieved by saw utting along the leaking joint and then filling the cut with an elastic sealant (Figure 2). The saw cut should be wide enough to span the joint and cut about 1/8 in. minimum into the concrete on each side of it. The cut must also be deep enough to penetrate any unsound, cracked, or deteriorated materials. Typically, a cut 1/2 in. wide by 1-1/2 in. deep is acceptable. If the monoliths are chamfered, the "V" formed by the chamfers can be used for the caulking if the concrete is in good shape. The saw cut should follow the joint to its base; otherwise, water migrating underneath the sealant can build up pressure in the joint behind the sealant.

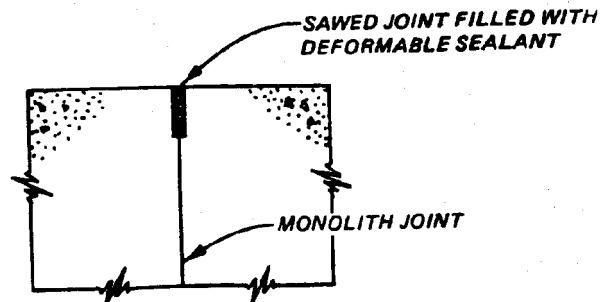


Figure 2. Typical sawed joint filled with sealant

- (2) Use. Since this technique is a surface repair technique, it is most useful when the reservoir level can be dropped below the elevation to which repairs are necessary and when the joint opening is not too great.
- (3) Advantage/Limitations. A large number of caulking materials can be used in conjunction with this technique (Ref c). These materials can facilitate many different types of joint caulking needs. Since the repair materials are essentially on the surface of the structure, they are easily removed if the repair is unsuccessful. If necessary, joints can be caulked in an under-water environment. This technique is economical, and the materials are easy to install if dewatering of the structure is not necessary.

However, this technique is limited if large movements between monoliths are expected. Large movements of the joint can stress some repair caulks beyond their elastic limit. In vertical joints, the caulk must be able to resist sag from gravity forces, and it must set rapidly and bond to cool dam concrete. It must also remain flexible under the anticipated service conditions. In some circumstances of joint closure, the caulk has a tendency to extrude from the joint if the joint is not augmented with a surface membrane. In many of these cases, a

surface plate has been used in conjunction with the caulked joint to resist extrusion of the caulking material as the monoliths expand.

c. Drill Holes Filled with Elastic Material;

- (1) Description. This approach (Figure 3) consists of drilling a large diameter hole from the top of the structure, along the vertical joint between monoliths, and filling the hole with an elastic material or a hole liner filled with an elastic material. Typically, the hole is 3 to 6 in. in diameter and is drilled by a "down-the-hole" hammer or core drill.

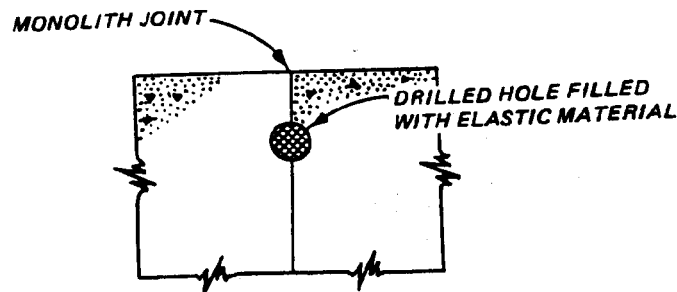


Figure 3. Drilled hole with elastic filler

- (2) Use. This procedure is typically used under conditions in which the site to install the remedial waterstop is not accessible from the face of the structure. For example, the site to install remedial repair might be just downstream of the damaged waterstop.

The drill holes are filled with an elastic filler material to create a seal against water penetration through the joint. Criteria for the filler require that it displace water, attain some degree of bond to the concrete surface, remain elastic throughout the life of the structure, be practical for field application, be economical, and have sufficient consistency so as not to extrude under the hydraulic head to which it will be subjected.

The design assumption is that the "poured-in-place" grout filler will form a continuous elastic bulb within the drilled hole. The filler will press tightly to the downstream side of the hole when water pressure is applied to the upstream side, thereby creating a tight seal. However, if the filler material, which is often in liquid form, travels out from the drilled hole during placement and into the joint before it sets, better sealing can be expected. Various types of portland-cement and chemical grout have been used as a filler.

- (a) Acrylamide grout systems have been used as elastic filler in several applications. Developed primarily for filling

voids in permeable sand and gravel foundations, these systems consist of an acrylamide powder, a catalyst, and an initiator. When dissolved in separate water solutions and mixed together, they produce a gelatinous mass.

- (b) Hydrophilic polyurethane gel and foam grout systems are hydraulic polymers which are activated when placed in contact with water. They cure to form a tough, flexible gel approximately 10 times their original volume. Under static water conditions, these materials can be simply poured into the drill hole. However, where significant water is present, one successful approach in using these materials is to pack burlap bags which have been saturated with the grout into the drill holes. Water in the drill holes activates the grout system causing the grout to expand and completely fill the holes (Ref c).

In some cases, continuous tube-type, flexible liners have been inserted into the drill hole to contain the filler material. These liners may or may not be bonded to the walls of the joint. Liner materials include reinforced plastic firehose, natural rubber, elastomer-coated fabric, neoprene, synthetic rubber, and felt tubes. A variety of materials have been used as fillers inside the drill hole liners. These include water, bentonite slurry, and various formulations of chemical grout.

Possibly the most successful of these types of repairs is the bonded liner which was used at Pine Flat Dam. A tube-type liner consisting of a thin polyurethane membrane with a 1/4-in.-thick underlayer of felt is used. Prior to insertion in the hole, the tube is filled with a water-activated resin such that the felt will become saturated. The tube is then placed over the top of the hole and through the use of air pressure, forced to turn itself inside out and down into the hole. This places the resin-saturated felt against the inside of the wet hole, and the water catalyzes the resin, bonding the tube to the inside of the hole. After the resin cures, the interior of the tube is filled with chemical grout to form the strong and flexible core (Ref c).

- (3) Advantages/Limitations. Core drilling and down-the-hole hammer drilling are two methods of drilling the hole across the joint. The more costly core drilling allows easy visual inspection of hole alignment along the joint; however, the down-the-hole hammer has proved to be the preferred method of drilling. Down-hole inspection of the drilled hole can be accomplished by small underwater video cameras. These cameras are very useful to inspect hole alignment and condition of the joint.

The successful filling of the joint with the chemical grout cannot be observed with this method. However, it has been suggested that one of the disadvantages of this method is that

regrouting can be done easily and economically by experienced chemical grouters.

With the acrylamide grout systems, large movements and high pressures can cause the repair material to extrude from the joint in a matter of months. The volume stability of the material is very dependent on the presence of moisture or fillers and stabilizers. Large relative movements have caused the material to fail.

The hydrophilic polyurethane foam grout procedure was used at Dardanelle Lock with a reduction in gallery leakage of approximately 95 percent.

d. Chemically Grouted Joints:

- (1) Description. This method makes use of chemical grout pumped through drilled holes and into cavities to be filled by the grout (Figure 4). Typically, an array of small-diameter holes is drilled from various locations within a gallery or other access point to intercept the joint behind the waterstop. An elastic, chemical grout is then injected through the drill holes to fill the joint.

Criteria for the injection grout require that it have low viscosity, gel or set quickly, bond to wet surfaces, be workable in and underwater, possess good elastic strength, and tolerate unavoidable debris.

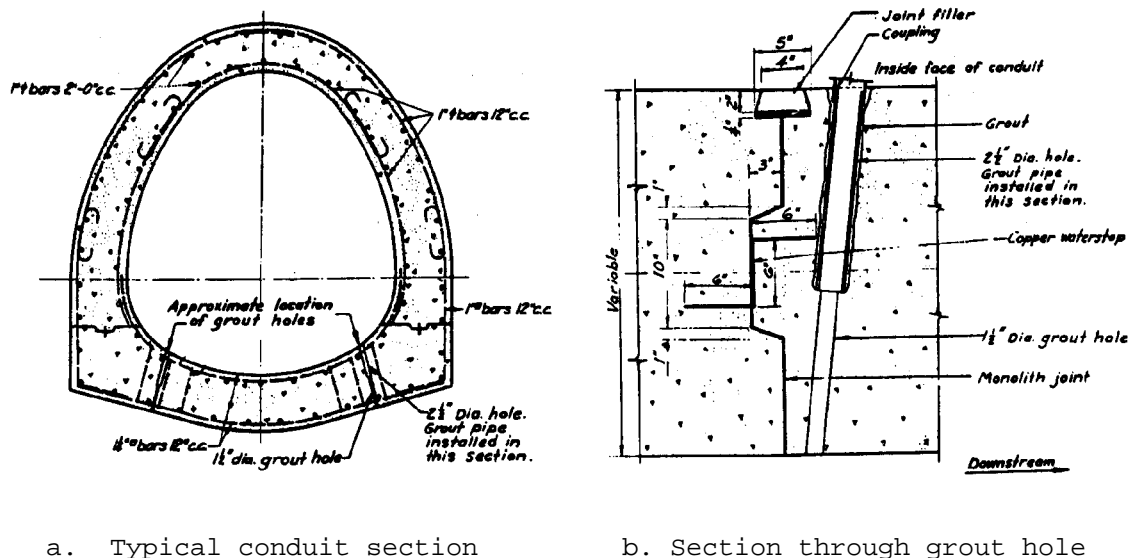


Figure 4. Original location of grout holes

- (2) Use. This method of remedial repair has been successfully used to seal isolated areas of interior joints to prevent leakage such as that around the perimeter of a drainage gallery where it crosses a joint and in contraction joints in regulating outlet conduits. It has also been used to seal exterior joints such as those on the upstream face of a dam. A permeable grout tube placed in the vertical "V" along the face of each joint and covered with an elastomeric sealant has been used to grout exterior joints. After the sealant hardens, the grout tube is injected with a sealant (polysulfide) to fill the joints from the dam face into the embedded waterstop. Prior to hardening of the sealant, a surface-plate waterstop is anchored into position over the joint.
- (3) Advantages/Limitations. In some instances, this is the only method of remedial waterstop repair that is feasible. However, it gives the advantage of drilling exactly where the problem is and placing the grout directly where it is needed.

Large-volume or high-pressure flows must be controlled during grout injection and curing. Materials and methods commonly used to control such flows include lead wool hammered into the joint, foam rubber or strips of other absorbent materials soaked in water-activated polyurethane and packed into the joint, and small-diameter pipes embedded in the packing material to relieve pressure and divert flow. If the joint opening is greater than approximately 0.1 in., a surface plate waterstop may be necessary within the gallery or conduit to prevent grout extrusion with time due to hydraulic pressure along the joint.

- REFERENCES:
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 - b. Schrader, E. K. 1980 (Oct). "Repair of Waterstop Failures," ASCE Journal of the Energy Division, Vol 106, No. EY2, American Society of Civil Engineers, pp 155-163.
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 - d. Headquarters, Department of the Army. 1986. "Evaluation and Repair of Concrete Structures," EM 1110-2-2002, Washington, DC.